Unlicensed Operation in the TV Bands

ET Docket No. 04-186

February 12, 2008

TVWS Interference Modeling

Presentation Goals:

Reiterate Motorola's position on TVWS interference modeling

Clarify the record on supported / suggested interference avoidance techniques

- Motorola has suggested numerous techniques covering both:
  - **Geo-location enabled TVWS devices**
  - **Sensing-only TVWS devices**

Reiterate the need for two-classes of TVWS equipment

TVWS Opportunity

Motorola strongly supports the Commission's proposals to make TVWS spectrum available

It is imperative for the overall success of the technology that *all* TVWS devices respect the rights of licensed spectrum users

- Motorola has strongly supported conservative interference modeling techniques in past filings (e.g., see *Oct. 18, 2007 ex-parte* filing)
- Motorola serves numerous licensed and unlicensed markets – both types of markets are critically important
- No one wins if WSDs cause harmful interference to licensed users

TVWS Interference Modeling History

Motorola supports conservative interference modeling in the TVWS

Contrary to recent MSTV statements on the record[1], Motorola has indeed considered adjacent channel (and many other) interference effects

- TVWS interference modeling closely approximates typical licensed TV band frequency planning / channel allocation process
- Interference effects & assumptions discussed in detail in Motorola *Oct. 18, 2007 ex-parte* filing (e.g., pp. 4-5, 7, 11, 20, 23-28…)
- Motorola agrees with past Commission proposals[2] for interference modeling
- Modeling relies on prescribed (co-channel, adjacent channel, etc.) D/U interference protection ratios and protected service contour levels set by the Commission
  - All of these levels can be altered in the field for geo-location enabled WSDs, through normal database access process (interference issues can be readily addressed)
  - Conceptually, there is guaranteed to be a safe protection limit for virtually all TV receivers in the field – it's just a matter of how much margin needs to be present…
- In many cases, these models are already highly conservative…

1. See *MSTV Dec. 18th, 2007 ex-parte* filing, slides 6-10.
2. See FCC NPRM, *May 25, 2004 (ET Docket No. 04-186), pp. 14-18.*

TVWS Interference Modeling Details

Adjacent channel interference modeling techniques

The Commission has previously proposed -26dB/-28dB (U/L) adjacent channel and 23dB co-channel (D/U) DTV interference protection ratios

- Adj. channel protection ratio itself is conservative (by ~6-13dB on avg.)
  - Past OET testing has revealed DTV receiver adj. ch. D/U closer to -40dB typ.[3]
  - ATSC A/74 DTV receiver adj. ch. D/U guidelines are -33dB
- Prescribed F(90,90) DTV signal propagation modeling is conservative (by ~12dB typ.)
  - Reduces expected received (adj. ch.) DTV signal strength by ~10-15dB (NTIA ITM model)[4]
  - Suggest the Commission standardize on readily available F(90,90) modeling tool

Motorola strongly supports separately modeling 'in-band' splatter effects[5]

- (In addition to modeling WSD->TV receiver adj. ch. interference effects above)
  - compute/estimate DTV co-channel interference caused by WSD transmitter splatter

Importantly, off-channel interference modeling should apply to both geo-location enabled WSDs and sensing-only WSDs (though methods differ)…

3. See OET report 07-TR-1003 "*Interference Rejection Thresholds of DTV Receivers…*", p. 5-12, 7/31/07.
4. See http://ntiacsd.ntia.doc.gov/msam/ITM/itm.htm (e.g., NTIA ITM F(90,90) model has 12dB more loss than F(50,90) at 1km distance, f=600MHz, delta h=200m (terrain roughness), 200m TX ant. ht., 9m RX ant. ht.).
5. See Motorola *Oct. 18th, 2007 ex-parte* filing, pp. 4-5, pp. 23-26.

Geo-location Interference Modeling Details

Geo-location WSDs:

Geo-location enabled WSDs can compute received TV signal strengths based on location to set max. transmit power levels & avoid causing interference

- Compute *conservative* F(90,90) TV signal E-fields at affected TV receiver location (e.g., at edge of 10m interference radius away from current WSD location, inside of adjacent channel contour),
- And apply *conservative* co-channel and adjacent channel (D/U) protection ratios to reduce WSD transmit power to limit co- and adjacent channel interference received at affected TV receiver[6]
  - Includes computing *both* WSD over-the-air on-channel emissions (which appear as *adjacent channel interference* to affected TV receiver),
  - *And*, WSD over-the-air (OOB) transmitter splatter (which appears as *co-channel interference* to affected TV receiver)
    - Takes into account actual transmitter splatter levels (e.g., based on WSD transmit mask)
- All models *conservatively* assume no reduction in WSD signal strength (additional discrimination) from directional TV receiver antenna *(or polarization mismatches)*
- Similar modeling applies to *nearest* protected contour edge when outside of contours
  - (e.g., propagate WSD in-band and out-of-band interference over-the-air to nearest contour edge and meet all required protection ratios at that location)
- Geo-location modeling is much more *predictable* than sensing-based modeling…

6. Both effects are described in the Motorola *Oct. 18th, 2007 ex-parte* filing, pp. 4-5, 23-26.

Geo-location WSD Operation

Geo-location WSDs (continued):

Geo-location enabled WSDs should be allowed to dynamically compute transmit power (up to 36dBm) vs. operating location in the field

- Using configurable interference protection ratios (from incumbent database) and *actual device characteristics* (e.g., OOB splatter levels, antenna gains, etc.)
- Including fixed-portable, portable and tethered portable devices (utilizing worst case location uncertainty concepts)[7]
  - Location uncertainty techniques also allow smaller stored database sizes (reduced memory req.)
- Higher power WSDs (e.g., >10dBm) should register when accessing database
  - Including device ID, operating region and operating times, etc. (possibly encrypted…)
- Database with well-designed framework readily allows for the introduction of new services (e.g., new DTV modulations, LMR, wireless mic deployments, etc.)
  - Can be permanent or temporary services (i.e., time-bound specified)
  - Could include information similar to the beacon (e.g., priority)

7. Location uncertainty techniques are described in the Motorola *Oct. 18th, 2007 ex-parte* filing, pp. 8-10.

Sensing-Only Interference Modeling Details

Sensing-only WSDs:

To avoid causing interference, sensing-only WSDs must infer adjacent channel signal strengths based on sensing measurements[8]

- Must apply a specified offset from all measured adjacent channel TV signal strengths to form an upper limit on WSD transmit power
  - Ex.: sensed DTV adj. ch. RSSI = -72dBm -> max. adj. ch. signal: -46dBm (-26dB D/U), assume 10m sqr. law prop loss of 48dB -> max WSD transmit power level = +2dBm (74dB DTV offset)
  - *Key Assumptions:*
    - Signal at TV rcvr. ant. is of similar strength to sensed signal (similar paths – *no additional offsets included*)
    - Adjacent channel signal can be *accurately characterized* as DTV/NTSC/etc., in order to properly apply correct protection ratios (may be tricky for noisy signals…) Otherwise, requires global protection ratios…
    - WSD device transmit mask assures WSD TX splatter is not an issue (not quite true with proposed Part 15.209(a) TX mask)
    - Otherwise, need to apply additional WSD transmit power restriction based on actual WSD TX OOBE levels (e.g., -95dBm max. DTV co-channel signal above (23dB D/U) with -40dBr/6MHz WSD adj. ch. splatter would limit WSD transmit power to [-95dBm + 40dBr + 48dB (PL)] = -7dBm)
  - *Implies the desire for a generally tighter TX spectral mask for sensing-only CR units*

8. As described in Motorola *Oct. 18th, 2007 ex-parte* filing, pp. 11, 20, 27-28. *Note that Motorola never claimed that reducing sensing-only WSD transmit power levels to 10dBm eliminates adjacent channel interference.* The proposed 10dBm level is merely a *maximum* transmit power limit (to be reduced as described above).

Sensing-Only WSD Operation

Sensing-only WSDs (continued):

In general, portable sensing-only WSDs are subject to a wide range of uncontrollable variables that affect sensed signal levels

- Ranging from variations in antenna height, antenna gain, and polarization effects to building penetration losses, fading, shadowing, etc.
- All of these effects increase sensing measurement variability (as does receiver linearity, temperature, operating frequency, phase noise/spurs, aging, manufacturing variations, etc.)
- As such, it would be wise to take a conservative initial deployment stance[9]
  - Suggest adding some degree of additional margin (e.g., ~5-15dB) to previously described sensing offsets to protect incumbents in the presence of the above effects
  - Suggest requiring (IEEE 802.22.1) disabling beacon reception capability, to maintain some level of control over fielded units (and potentially enforce priority/orderly co-existence among WSDs)
  - Additional sensing level uncertainty implies generally requiring a tighter transmit mask to help control WSD TX OOBE (e.g., Part 15.209(a) vs. simple LP-DTV mask)
  - Suggest stringent DTV detection levels (e.g., -116dBm), realistic faded channel testing, & max. falsing rate requirements (e.g., <10%) to avoid artificially inflating detection results, while maintaining spectral efficiency
  - Suggest limiting transmit power (to 10dBm EIRP) until further test data/field experience is gathered (additional layer of protection) - also avoids direct pick-up issues in cabled systems

9. As described in Motorola *Oct. 18th, 2007 ex-parte* filing, pp. 21-22.

“Ideal” WSD Transmit Masks

“Idealized” WSD transmit spectral mask:

The following mask is ideal in the sense that if DTV adjacent channel (D/U) protection ratios are met, then DTV co-channel protection ratios (from WSD TX splatter) will also be met:[10]

Channel	D/U ratio (dB)	Off-channel emissions (dBr/6 MHz)
N	+23	--
N ± 1	-26	-49
N ± 2	-44	-67
N ± 3	-48	-71
N ± 4	-52	-75
N ± 5	-56	-79
N ± 6 - 13	-57	-80
N ± 14, 15	-50	-73

The ideal mask would be difficult to implement in a low-cost, variable operating frequency WSD

- However, as long as a WSD is able to take into account it’s actual/estimated TX splatter levels (either directly or indirectly), it should be allowed to transmit, *though at lower power levels that ensure at least both adjacent and co-channel protection to incumbent receivers*
  - Generally easier to accomplish in geo-location enabled WSDs (allows D/U updates & less margin needed)
  - WSDs with worse transmit splatter (OOBE) will be penalized with lower transmit power levels
  - Allows the market to decide suitable price/performance points (application dependent)
  - Note that 23dB DTV C/I requirement can be considered conservative for stronger signals
  - Minimum performance TX mask still advisable for good/stable system design

10. As described in Motorola *Oct. 18th, 2007 ex-parte* filing, pp. 24-26.

Additional Interference Protection

May potentially include additional interference protection in all WSDs

Given DTV receiver test results[11], it may be wise to require *reasonable alternate channel* (e.g., N±2) interference modeling in determining maximum allowable WSD TX power

- Utilizing similar methods as previously described (*applies to both geo-location computations and sensing measurements with prescribed D/U offsets*)
- Once again, includes modeling *both alternate channel interference protection ratios* (e.g., A/74 44dB for N±2) *and WSD alternate channel TX splatter* (which falls co-channel to affected rcvr.)

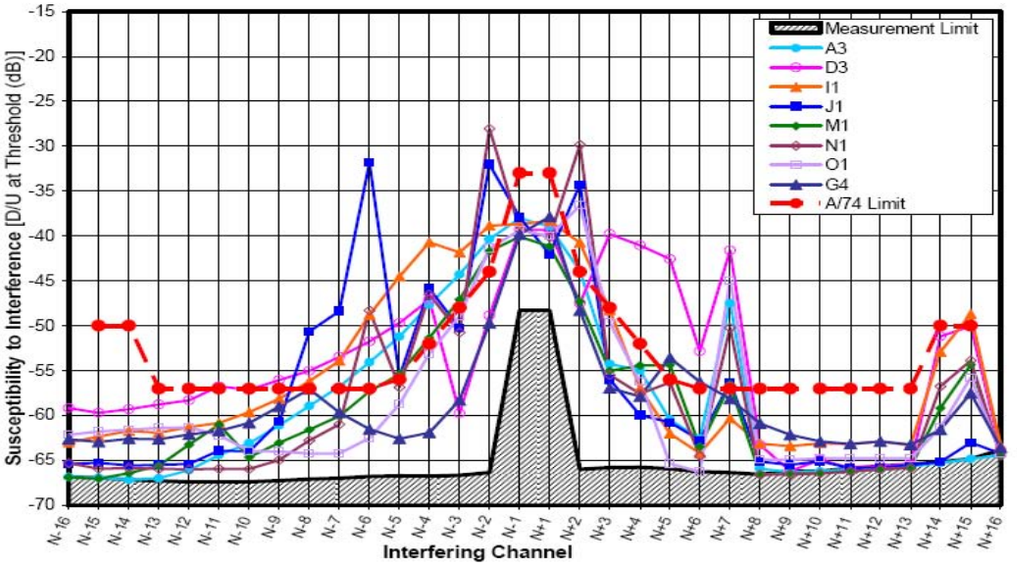


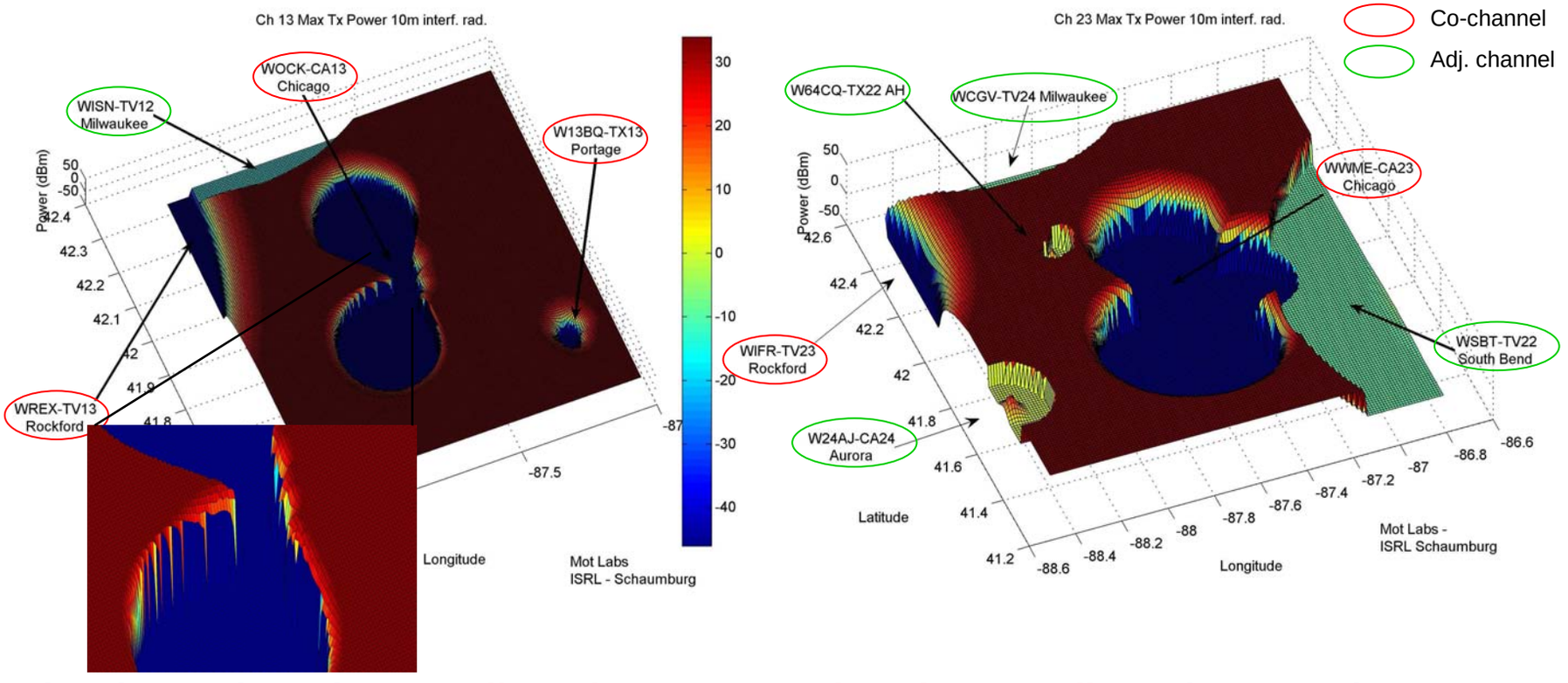
Figure 5-1. D/U of 8 Receivers at D = -68 dBm on Channel 30

11. See OET report 07-TR-1003 "*Interference Rejection Thresholds of DTV Receivers…*", p. 5-12, 7/31/07.

Backup Slides

Geo-location Database Modeling Examples

Max Allowed WSD EIRP vs. Lat-Long Coordinates



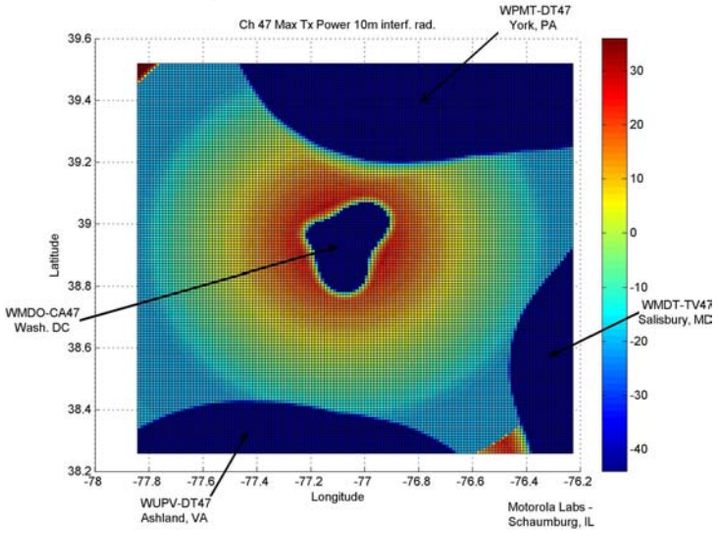
The charts show the Max allowed EIRP versus location coordinate for operation on TV channels 13 (left) and 23 (right) in the Chicago area

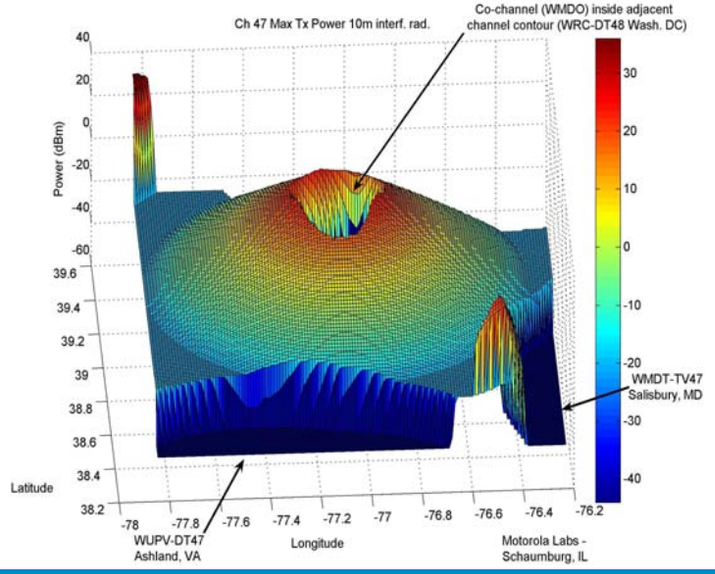
The color code indicates the allowed EIRP in dBm to satisfy various co- and adjacent channel interference criteria, taking into account the different protection requirements for different classes of licensed stations – also includes nearest contour edge modeling (shown in magnified region)

Reddish-brown indicates >+30 dBm, dark blue <-45 dBm (essentially unusable)

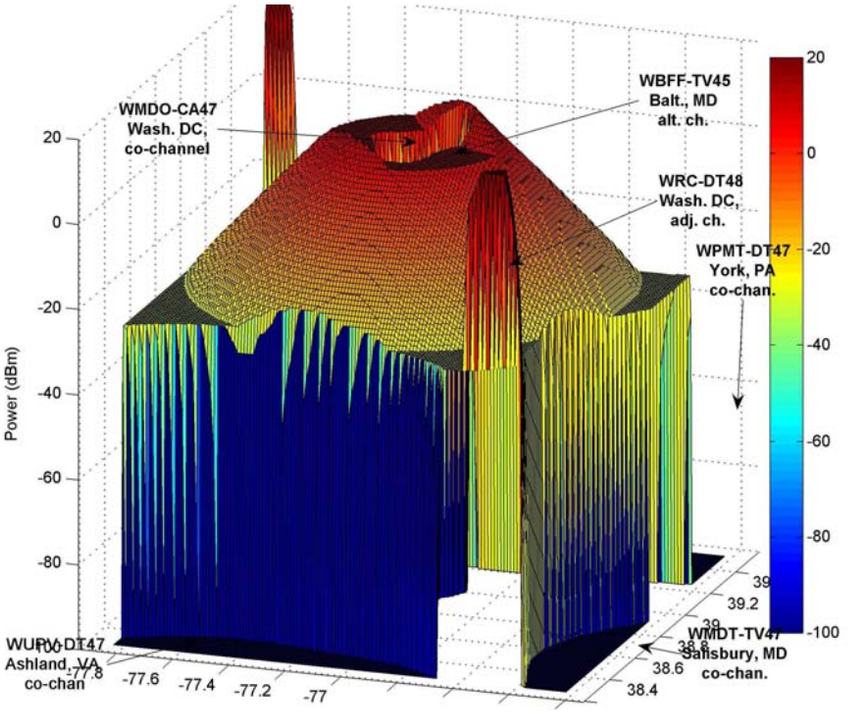
Geo-location Database Modeling Examples

max TX power with alternate channel interference modeling enabled…





Ch 47 Max. TX Power 10m interf. rad.



Note: upper plateau due to alternate channel station (Ch 45)

MOTOROLA

Additional WSD Considerations

Additional geo-location database considerations

Strongly suggest utilizing 'Provide_Protection' flags or equivalent in CDBS-like database

- For unambiguous identification of stations needing protection (e.g., LIC, CP-MOD, CP status, etc.) – could also be addressed by priority scheme (e.g., must always protect highest priority levels)

Could also directly include radial HAAT data to aid in modeling terrain effects

- Put data into flat TVWS TV transmitter (CDBS-like) database/files (e.g., w/5-10^{o} radials)

Could require standard incumbent TX antenna elevation pattern modeling…

- E.g., OET 69-like vertical pattern modeling (for more accurate urban modeling)…

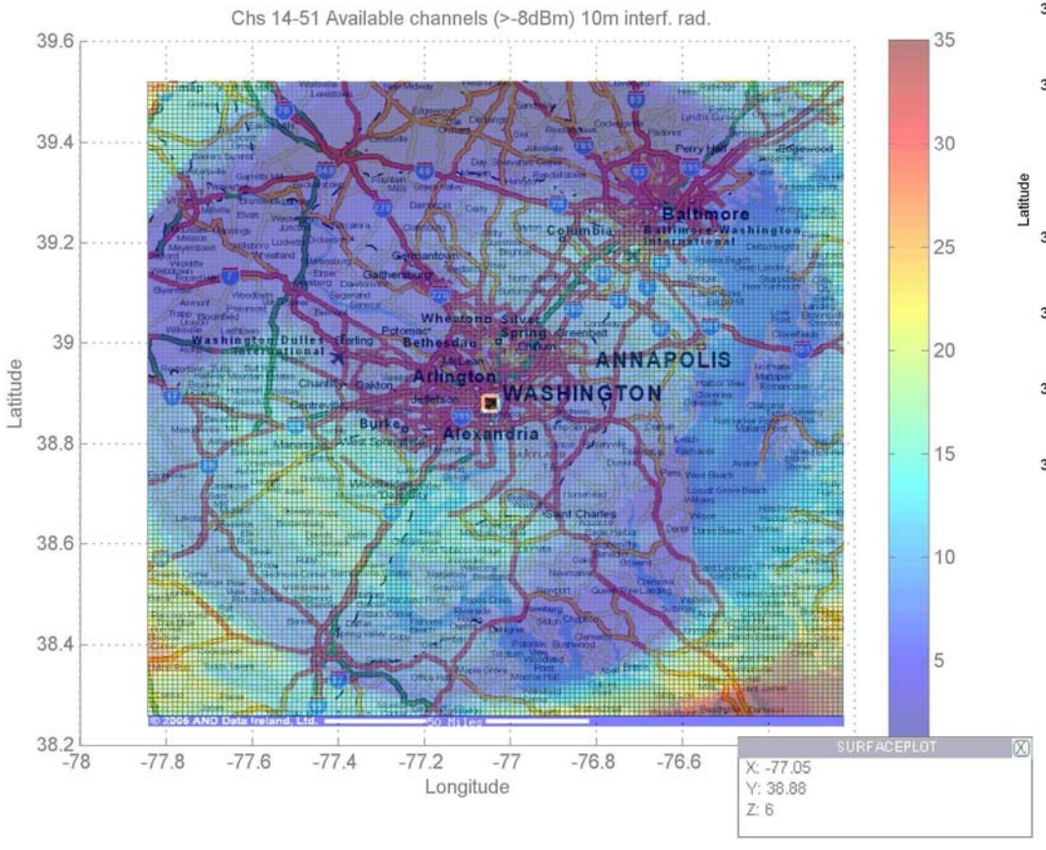
Protected service contour levels and (D/U) protection ratios already specified for low-power and full-power DTV/ATV, but *can easily be scaled to other services*

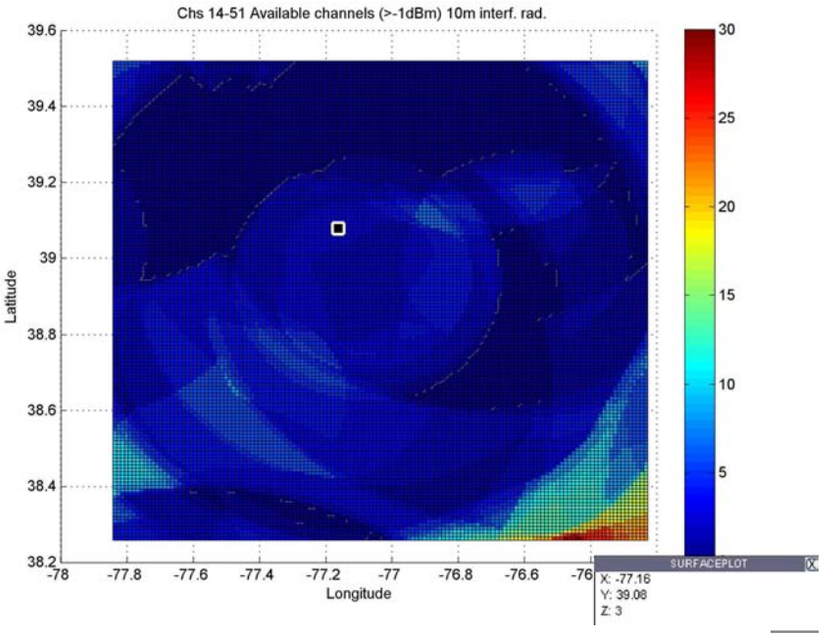
- Could be extended to protect other services where locations can be determined (e.g., wireless mics, LMR, future services in TV bands, etc.)
- Readily achieved with geo-location enabled WSDs, since dynamic update framework already in place

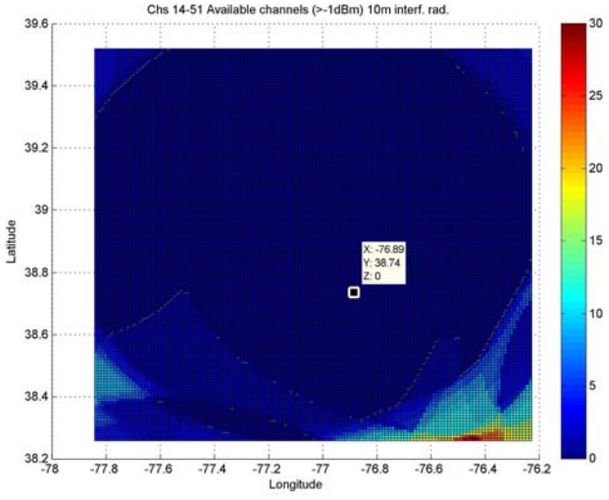
Disabling beacon approach (as in IEEE 802.22) assures *real-time protection* to those services that need it (e.g., wireless mics) that are not in the database

- Particularly important for sensing-only CR devices – only method of control
- Supports priority levels/orderly co-existence among TVWS services

DC Area Available TVWS channels

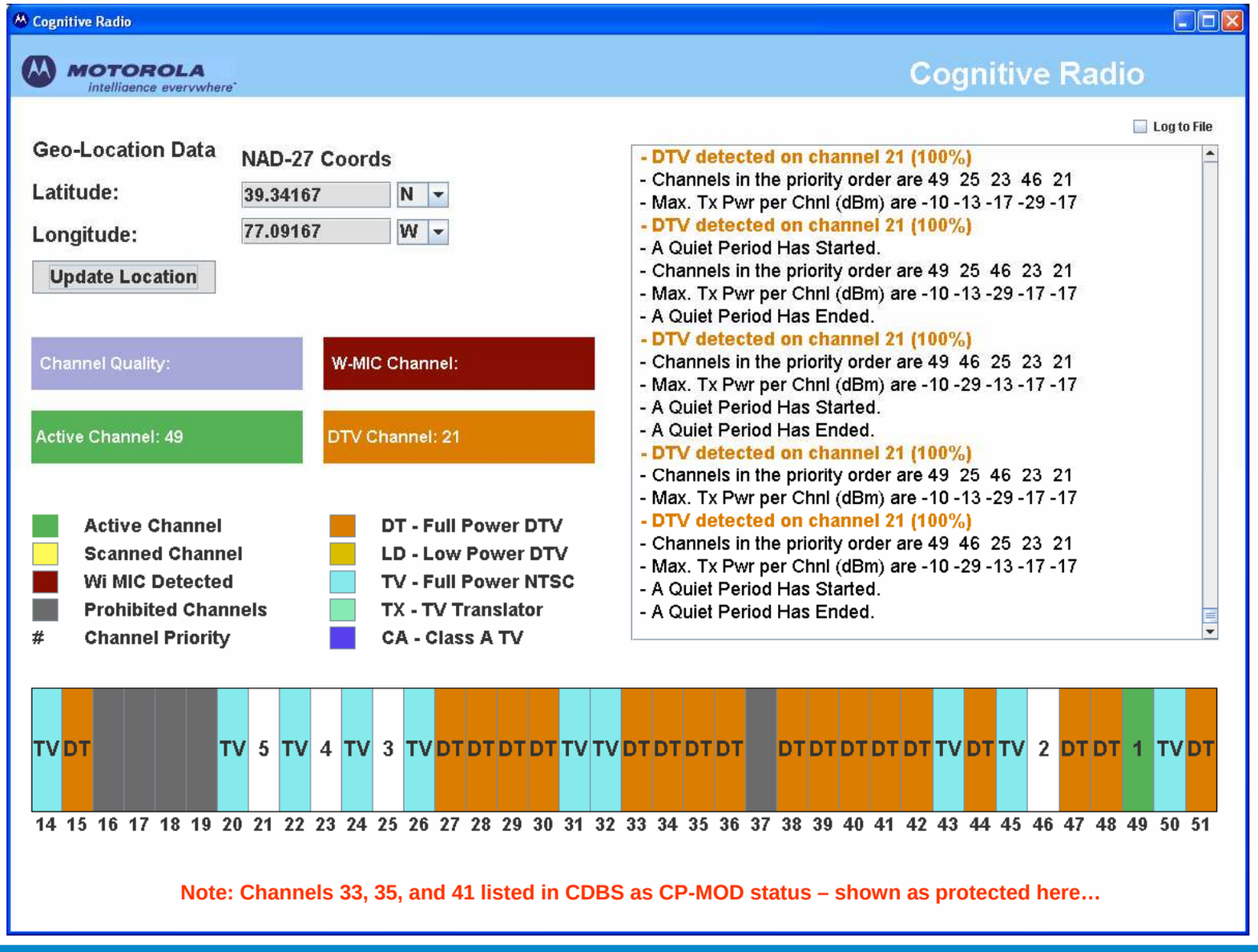






Notes:
- Maps shown for *current* TV band allocations
- Do not include CP-MODs that are on the air
- (Upper right doesn't attempt use of LMR adj. channels)
- (Lower right does not allow use of TV adj. channels)

Sample Motorola WSD GUI (including protection for all CP-MODs)



Note: Channels 33, 35, and 41 listed in CDBS as CP-MOD status – shown as protected here…

Comments on WSD Testing

Recall that the Motorola experimental prototype WSD relies on a geo-location database for incumbent (TV) detection and protection

Test Mode: Sensing Results >

UHF Channel	DTV presence probability % (100 tries)	DTV Detect > 50%	Ptotal dBm min	Ptotal dBm max
27	49.0	No	-86	-85
28	0.0	No	-89	-88
29	100.0	Yes	-78	-78
30	0.0	No	-89	-89
31	51.0	Yes	-81	-81
32	95.0	Yes	-79	-79

This column indicates final WSD decision on channel for whether DTV present or not!

- Sensing performed to *supplement* database results (i.e., help rank available channels)
  - Any DTV presence probability ≥ 50% (i.e., 'Yes' in DTV Detect column above) moves the scanned channel to the bottom of the candidate channel list (so it will not be used)
  - Sensing results should be averaged over numerous trials (covering several fading cycles), possibly performed during several quiet periods on the channel in practice
  - Motorola WSD performs short individual scans/trials very quickly (<3ms), and combines results…
  - Ultimate sensing time limit comes down to how long WSDs are allowed to sense before detecting/ declaring incumbent present and vacating channel (e.g., 10 seconds to detect DTV signal)
- To be fair, channel observation times for sensing should be equal among tested WSDs
  - For fading channels, should either be averaged over duration of test signal (e.g., 24 seconds), or limited to some max. observation time (e.g., 10 seconds)